Benefits and Costs to Rural Alaska Households from a Carbon Fee and Dividend Program

WORKING PAPER – COMMENTS SOLICITED

prepared by

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Summary

This paper analyzes the benefits and costs of a carbon fee-and-dividend (CFD) policy to individual rural Alaska households. The three study area regions are the Bethel Census Area, the Wade Hampton Census Area, and the Northwest Arctic Borough. These three regions have the state's highest fuel prices and very cold climates.

The CFD policy consists of two elements. The first is a fee of $15 per metric ton of CO2 beginning in 2016 and increasing by $10 per ton in each subsequent year. The second is the complete return of all fees to households in the form of dividends, which are estimated to equal $300 for each adult plus $150 for each child (up to two). The annual dividends would increase in future years commensurate with the total amount of fees.

Baseline conditions. The study area has a total population of about 32,000 people, many of whom live in large households with low cash income. Fuel prices averaged $6.62 per gallon in January 2015.

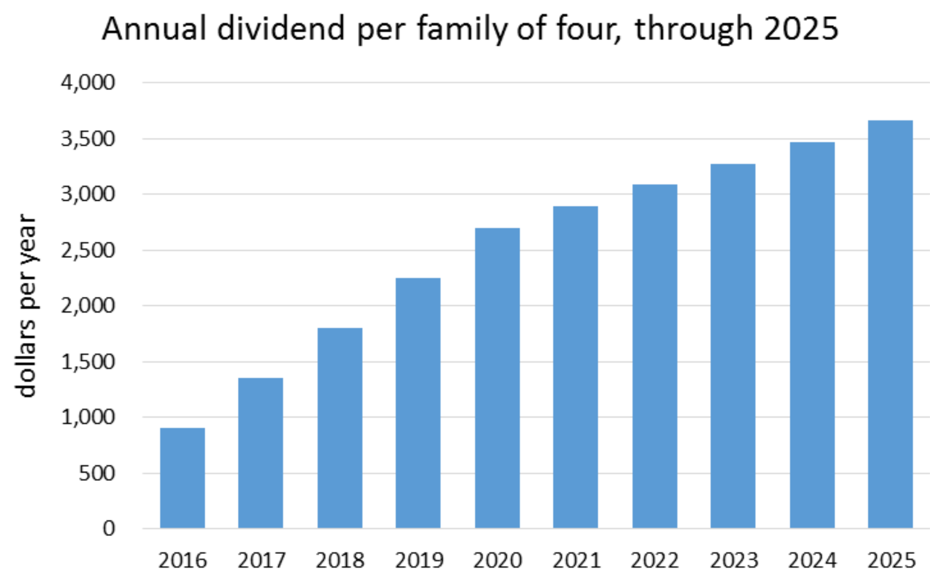
	Bethel Census Area	Northwest Arctic Borough	Wade Hampton Census Area	Overall Study Area
Baseline conditions:				
Population	17,013	7,523	7,459	31,995
Households	4,651	1,919	1,745	8,315
Average household size	3.7	3.9	4.3	3.8
Median household income	51,689	61,607	40,176	[1]
Average fuel price, Jan 2015	6.68	6.59	6.51	6.62

note [1]: median income cannot be calculated for the overall study area.
sources: U.S. Census 2010 (population, households, income); *Alaska Fuel Price Report: Current Community Conditions January 2015*
http://commerce.state.ak.us/dnn/Portals/4/pub/Fuel_Price_Report_Jan-2015.pdf

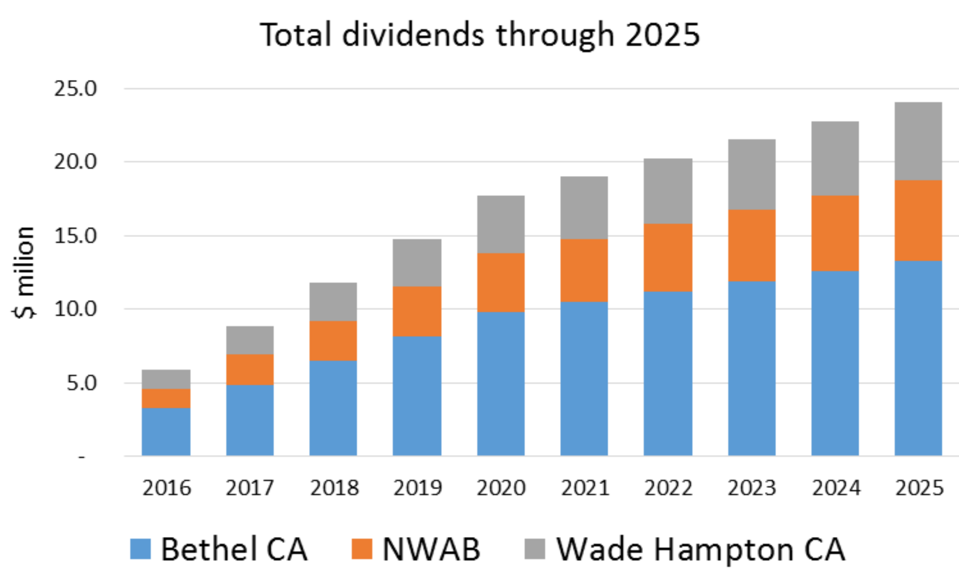
Methodology. Carbon fees paid by a household depend on the quantity of energy used, while dividends depend on household size. Both energy use and household size vary widely and more or less independently among individual households. It is critical to consider this variation when evaluating the CFD policy; the "average" outcome reveals very little about the distribution of dividends and fees. Existing household-level data are adequate to calculate dividends, but not fees. This analysis therefore uses community-level data to generate fee and dividend amounts for representative "small" (1-2 persons) and "large" (3+ persons) households in each region. Although this approach is admittedly imperfect, it represents a significant first step toward understanding the consequences of a CFD policy for individual rural Alaska households.

Major findings

- A family of two adults and two or more children would receive a dividend of $900 in 2016, increasing to more than $3,600 by 2025.[1]

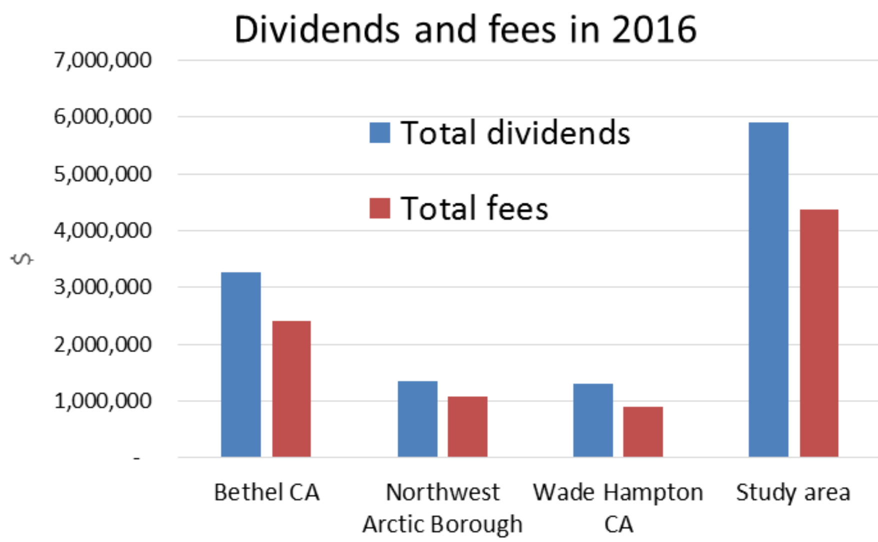


- A total of $5.9 million in dividend payments would flow to the three regions in 2016. Total dividends would increase to $24 million by 2025.



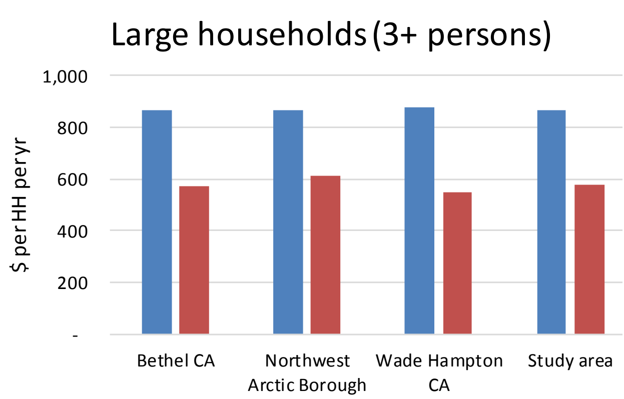
[1] All amounts are real dollars of year 2016 purchasing power.

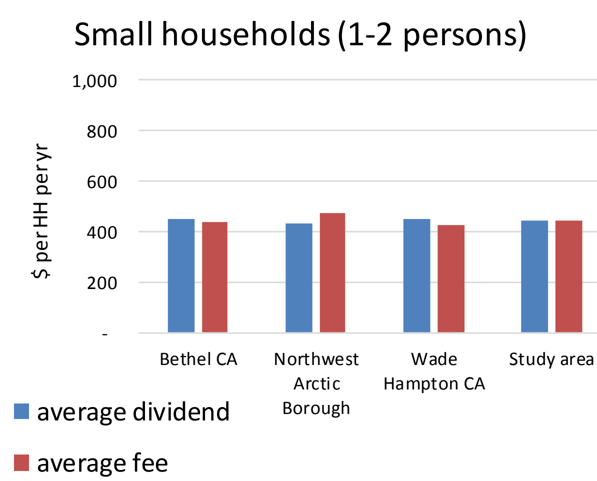
- Total dividends initially exceed total fees in all three regions, resulting in a net cash benefit of $1.5 million flowing into the study area in 2016.



- Large households (3+ people) in all three regions would receive average initial dividends that exceed fees by more than $250 per year, with the largest net cash benefit of $328 per household going to the Wade Hampton Census Area. Large households represent 86% of the study area population.

- For small households (1-2 people), average initial dividends would slightly exceed fees except in Northwest Arctic Borough, where fees would exceed dividends by $41 per year. These small households represent 10% of the borough population.





- Overall, More than 91% of all households in the study area, comprising 97% of the population, would receive average dividends exceeding average fees in 2016. While there are undoubtedly financial winners and losers within each household group, it is reasonable to conclude that the vast majority of people in the study area stand to initially gain more in dividends than they would pay in fees.

- These net benefits would likely increase over time, but future outomes will also very likely depend on further progress within the study area regions to increase energy efficiency and to displace diesel with low-carbon sources such as natural gas, propane, or renewables.

Summary of results for 2016

	Bethel Census Area	Northwest Arctic Borough	Wade Hampton Census Area	Overall Study Area
Initial year dividends and fees				
Total dividends	3,257,550	1,346,550	1,306,500	5,910,600
Total fees	2,408,276	1,077,897	891,042	4,377,214
Net cash benefit to region	849,274	268,653	415,458	1,533,386
Small households (1-2 people)				
Average dividend per HH	447	434	448	444
Average fee per HH	438	475	424	444
Average net cash benefit per HH	9	(41)	24	(0)
Number of households	1,846	727	518	3,091
Share of population	16%	15%	10%	14%
Large households (3+ persons)				
Average dividend per HH	867	865	876	869
Average fee per HH	570	615	547	575
Average net cash benefit per HH	297	250	328	294
Number of households	2,805	1,192	1,227	5,224
Share of population	84%	85%	90%	86%

1. Introduction

This paper uses the best available data to estimate the benefits and costs to rural Alaska households of a Carbon Fee and Dividend (CFD) policy. Policymakers have legitimate concerns about the effects of any measure that would add to the burden of high energy costs in rural Alaska, where heating fuel prices consistently exceed $6.00 per gallon in several regions and very cold temperatures contribute to high heating fuel consumption.

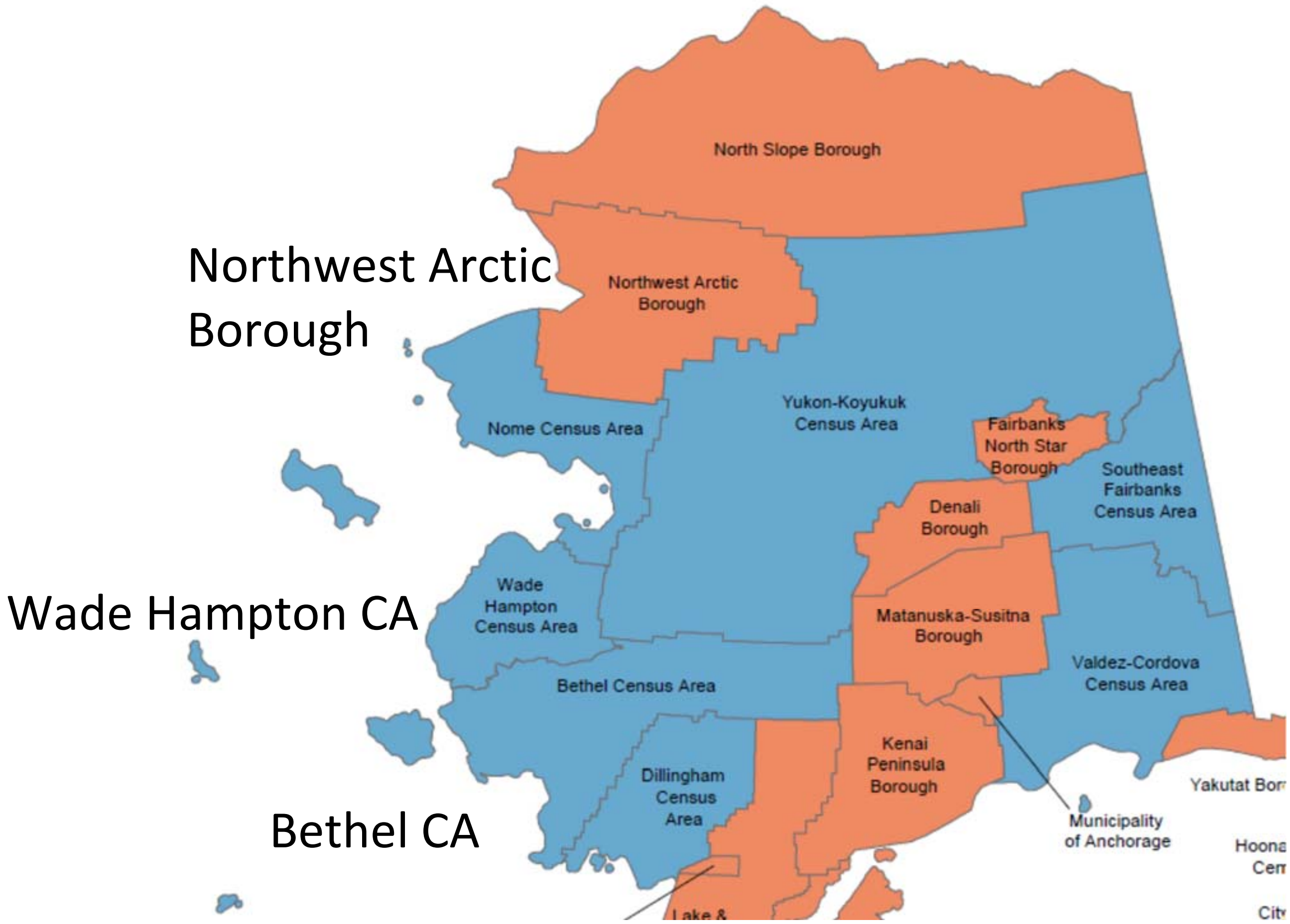
Under the CFD policy the fees are based on the quantities of electricity and fossil fuel consumed while the dividends to a household depend on household size. It is important to keep in mind that the CFD policy would add a fixed *dollar amount* per gallon to the price of fuel, rather than a fixed *percentage*. What matters most for how a household fares under the plan is the quantity of fuel used, not the price. Because they have been living with high prices, cold winters, and low cash incomes for a long time, many rural Alaska households use relatively low amounts of electricity and heating fuel. A large household using small quantities might come out well ahead, with dividends exceeding fees by a significant amount.

Two features of the analysis are noteworthy. First, following the general approach of "consumption-based emissions accounting" (Kummel 2014), I consider both direct household energy consumption and also indirect consumption where the cost is paid by other parties but then passed through – at least partly – to local residents. Second, the analysis attempts to get beyond regional averages to explore effects on individual households. Due to a lack of household-level data, I use community-level data to generate fee and dividend amounts for representative "small" (1-2 persons) and "large" (3+ persons) households in three different regions. Although this approach is admittedly imperfect, it represents a significant first step toward understanding the consequences of a CFD policy for actual rural Alaska households.

Conceptual approach

The study area consists of the Bethel Census Area, the Wade Hampton Census Area, and the Northwest Arctic Borough (Figure 1). These three regions have the state's highest fuel prices, low median incomes, and very cold climates (Table 1). Each region is analyzed separately. By using these three regions as case studies, the analysis helps to show how people throughout rural Alaska might fare under the CFD policy.

Figure 1. Study area



Map source: Alaska Department of Labor and Workforce Developmenr

Table 1. Study area baseline conditions

	Bethel Census Area	Northwest Arctic Borough	Wade Hampton Census Area	Overall Study Area
Baseline conditions:				
Population	17,013	7,523	7,459	31,995
Households	4,651	1,919	1,745	8,315
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http://commerce.state.ak.us/dnn/Portals/4/pub/Fuel_Price_Report_Jan-2015.pdf

The Carbon Fee & Dividend policy has the following key elements:

- The initial fee is $15 per metric ton CO2, increasing by $10 per ton (in real dollars) in each subsequent year.
- The initial dividend is estimated to be $300 per adult plus $150 per child for up to two children per household.[2]
- The carbon dividend amounts increase annually consistent with growth in the national total of fees received.[3]
- The carbon emission factors and the resulting initial fees per gallon are as shown in Table 2.

Table 2. Carbon emission factors

	kg CO2 / mmbtu	mmbtu / gal	kg CO2/gal	fee $/ton	fee $/gal
diesel for electricity	73.15	0.134	9.80	15.00	0.147
heating fuel	73.15	0.134	9.80	15.00	0.147
gasoline			8.91	15.00	0.134
jet fuel			9.57	15.00	0.144
avgas			8.32	15.00	0.125
aviation fuel average			9.00	15.00	0.135

The analysis uses direct data where possible. I also use or develop best estimates of key assumptions derived from statewide data or other published sources. As noted above, the general approach is to consider both direct payments and indirect payments by households for energy. Direct payments are out-of-pocket payments for residential electricity, residential heating fuel, and personal transportation fuel. Indirect payments are caused by items such as commercial electricity or heating fuel for the school. While these costs are initially paid by other entities such as local businesses, the school district, or state or federal government, they are ultimately paid *in part* by local residents in the forms of higher retail prices, taxes, or fees.[4] Indirect payments also arise from energy costs embodied in the prices of goods and services, notably air transportation and air freight.

Section 2 analyzes the amounts of money that households would receive as dividends. Section 3 estimates the carbon fees that households in each region would pay and compares fees to dividends. Section 4 concludes with discussion.

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[2] initial dividend amounts are estimated from current CO2 emissions.

[3] I used projections of future dividend amounts per household from REMI (2014), figure 3.18.

[4] The question of "who ultimately pays" is the age-old problem known in economics as *tax incidence*.

2. Dividends to households

Census data on the number of households of varying sizes allows for a precise calculation of how much money individual households would receive as dividends in each study region.

Figure 1 shows how households vary by size in each region. Table 3 summarizes the way that household sizes translate into dividends per household, and how the number of households of each size then determines total amount of cash dividends that would come into the region. A total of almost $6 million would flow into the study area in the first year. The assumption that all large households have no more than two adults is for simplicity; in reality many households of 3+ people might have 3 (or more) adults and receive annual dividends exceeding $900.

Figure 2. Distribution of households by household size

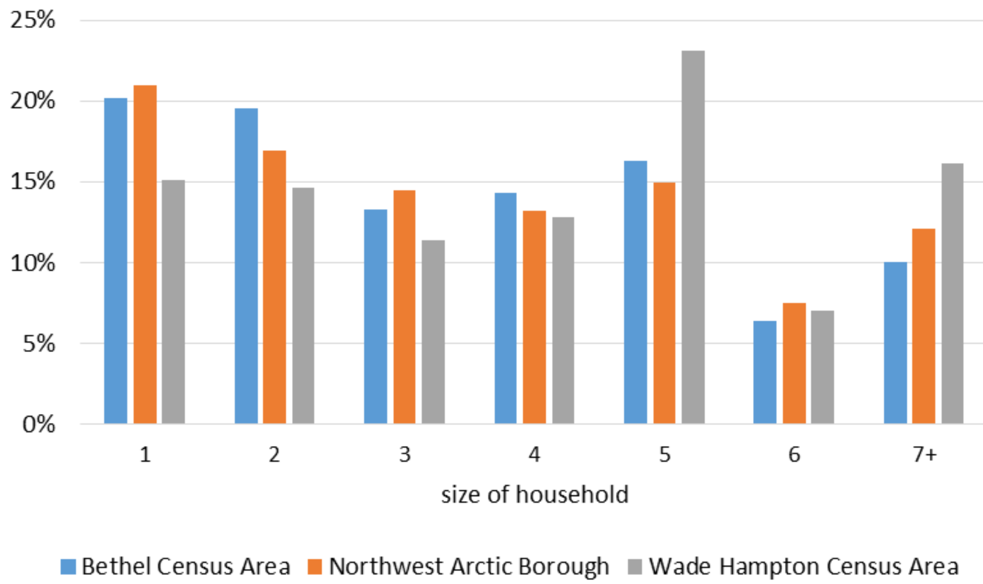


Table 3. Dividends per household and total dividends going to each region in 2016

	Household size							
	1	2	3	4	5	6	7+	Overall
dividend per HH:	$ 300	$ 600	$ 750	$ 900	$ 900	$ 900	$ 900	
Bethel Census Area								
# households	939	907	619	665	759	295	467	4,651
median income	21,181	65,650	42,500	51,442	64,338	52,614	61,964	
total dividends	281,700	544,200	464,250	598,500	683,100	265,500	420,300	3,257,550
Northwest Arctic Borough								
# households	403	324	277	253	287	143	232	1,919
median income	34,028	58,977	83,125	66,667	61,667	66,500	69,063	
total dividends	120,900	194,400	207,750	227,700	258,300	128,700	208,800	1,346,550
Wade Hampton Census Area								
# households	263	255	198	223	403	122	281	1,745
median income	16,131	34,063	37,656	40,833	39,563	47,500	57,857	
total dividends	78,900	153,000	148,500	200,700	362,700	109,800	252,900	1,306,500

For a household of two adults and two children, the annual dividend would start at $900 in 2016 and grow to more than $3,600 by 2025 (Figure 3).

Figure 3. Growth in the annual dividend to a family of four

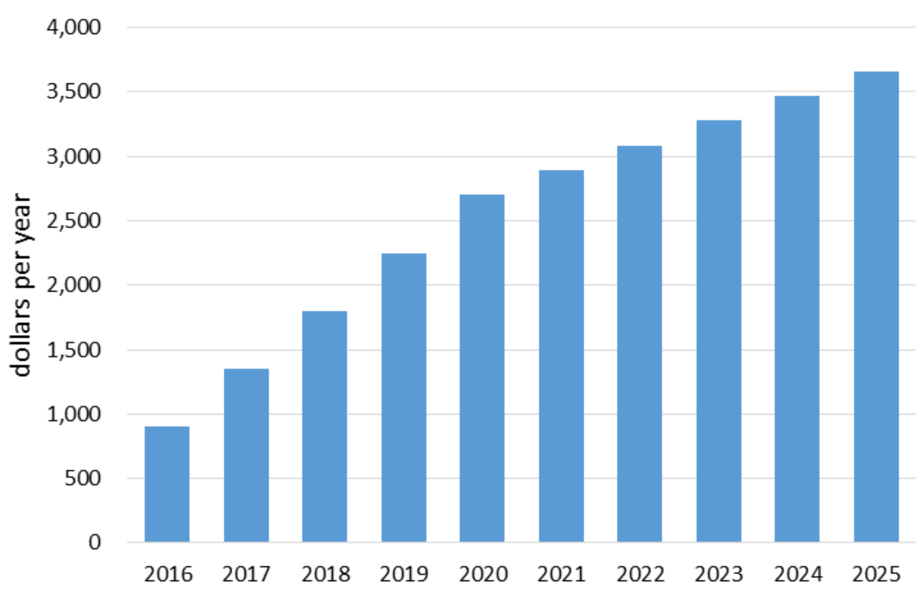
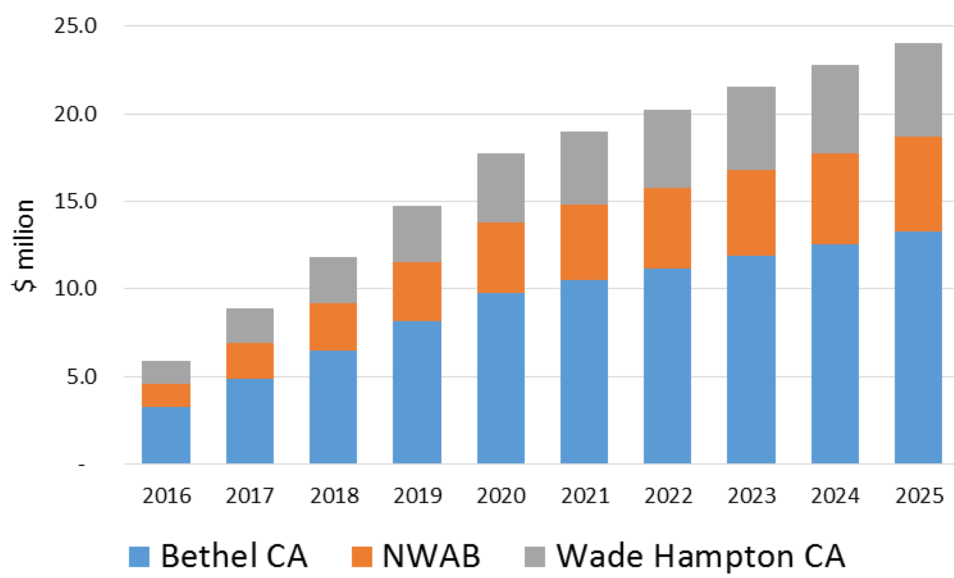


Figure 4 shows how total dividends to study area households would grow to almost $25 million by 2025. This projection is based on national studies of how the total dividend pool would grow due to the increased fee per ton (REMI 2014). The growth of dividends is less than the growth in the fee per ton since total carbon emissions decrease over time in response to the fee.

Figure 4. Growth of total dividends flowing to the study regions



3. Carbon fees paid by households

Fees and dividends paid by the "average" household

It is easy to calculate the direct fees paid and the dividends received by the "average" household in a region. For example, using the data and methods described below, the total use of diesel fuel and gasoline in the Bethel Census Area for all electricity (residential, commercial, community, government), for all space heating (residential, commercial, community, government) and for personal land and water transportation equates to about 1,121 gallons per person per year. The average household size is 3.6 persons. Therefore in the first year the average household would pay about $591 in fees and receive about $849 in dividends. For this average household dividends would exceed fees by $258.

Variation among households

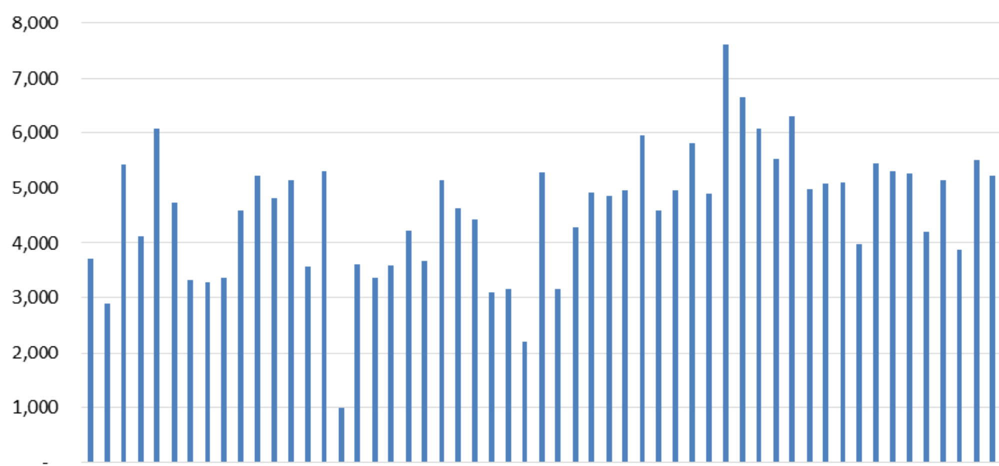
There are two main problems with this simple calculation using averages. The first problem is that it fails to add the additional energy embodied in good and services (like air freight) and fails to subtract the portion of nonresidential electricity and heating fuel that is likely not paid for by residents. This problem can be addressed through a more thorough analysis of these uses and payments.

The second, and far more serious, problem is that the "average household" is a statistical fiction that represents few, if any, actual households. There is tremendous variation in energy use, household size, and income among the 8,315 households in the study area. The main factor affecting the fee amount is household energy use and the main factor affecting the dividend amount is household size – both the number of adults and the number of children. Household income and spending are also important to the outcomes realized by particular households.

The following figures give some sense of these variations. Figure 2, above, showed the distribution of household sizes within the study area. The distribution is noteworthy for its "flat" shape – *not* like a bell curve with most households near the average. Too, the distribution itself seems to be noticeably different in different regions.

Figure 5 shows how the *community average* residential kWh per customer varies by a factor of 8 across study area communities.[5] The variation across individual households is likely to be at least as high as this variation in community averages.

Figure 5. Variation in average residential kWh across study area communities

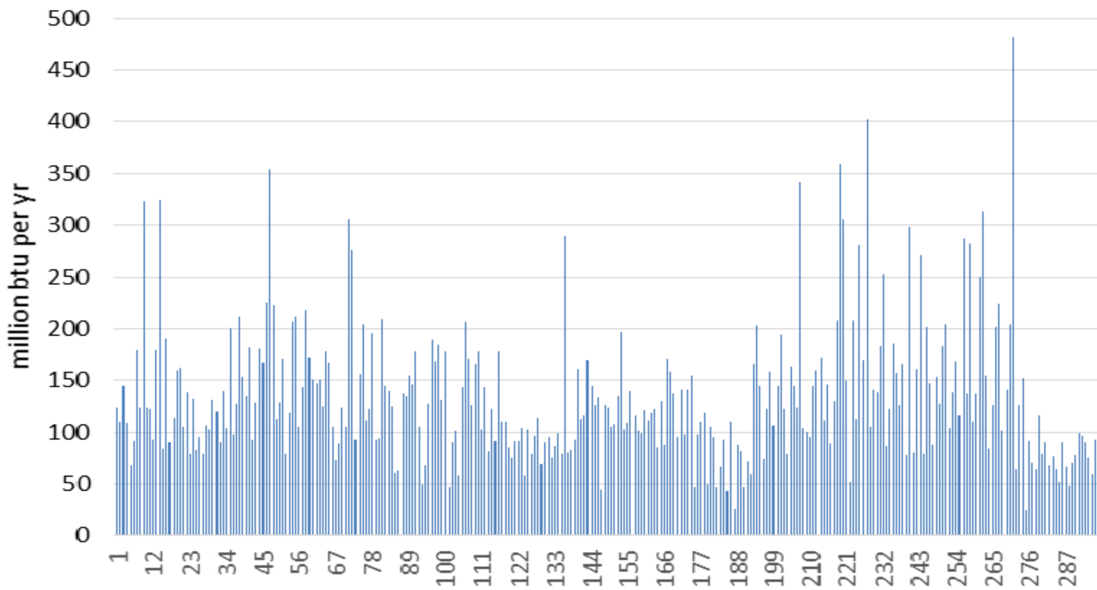


source: Alaska Energy Authority, Power Cost Equalization Program

[5] The raw data are from the Power Cost Equalization Program (PCE) statistical databases provided directly by the Alaska Energy Authority.

Figure 6 shows the variation in modeled heating fuel use by 297 single-family houses in the study area.[6] Each house was given an energy audit and the house characteristics were fed into the same modeling software. Therefore, this figure provides a reasonable gauge of the variation across individual households. The variation is once again about 10-fold.

Figure 6. Variation in modeled heating fuel usage across 297 individual houses in the study area

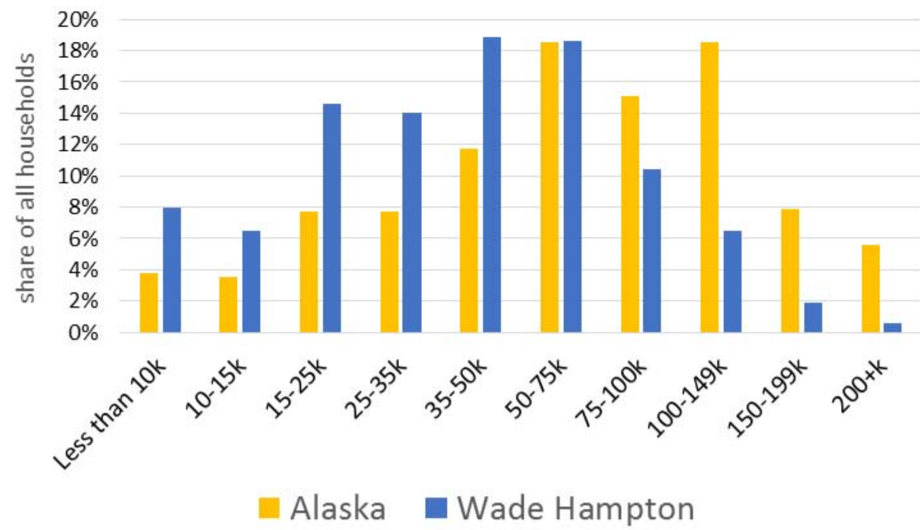


source: Alaska Retrofiit Information System; Alaska Energy Authority & WH Pacific, Alaska End Use Study (2012)

Finally, Figure 7 shows the distribution of household income for one of the three study regions – the Wade Hampton Census Area. Household incomes in the study area are more concentrated among lower income levels than they are for the state as a whole.

[6] These data are from the Alaska Retrofit Information System (ARIS), provided by the Alaska Housing Finance Corporation. This sample of 297 single family houses was extracted for analysis as part of the Alaska End Use Energy Study. http://www.akenergyauthority.org/Efficiency/EndUse

Figure 7. Distribution of household income in Alaska and in Wade Hampton



source: American Community Survey, 2013 5-yr estimates

Using two household types to capture variation

The ideal way to deal with all of this variation would be to conduct a household survey that measured energy use, household size, and spending patterns. The resulting household-level data set could be used to estimate the fee and dividend amounts for each household in the sample and, by extrapolation, for each household in the study area population. However, no such household-level data are available.[7]

This analysis therefore proceeds by constructing two different representative household types, denoted as “small” and “large.” I define “small” households to be those with 1 or 2 persons and “large” households to be those with 3 or more persons. For each type I estimate electricity, space heating, and transportation energy use, as well as household size, in such a way that the estimates are consistent with all available community and regional data for both types added together. I use two household types, rather than 3 or 4, in an attempt to capture significant variation among households while remaining solidly grounded in data and using a minimum number of *ad hoc* assumptions.

This methodology is described and applied in the following section, using Wade Hampton Census Area as an example. Results are then given for the Bethel Census Area and the Northwest Arctic Borough.

[7] The American Community Survey Public Use Microdata Sample (PUMS) provides some household-level data, but it falls far short of what is needed. I discuss use of the PUMS data in Section 4, below.

Carbon fee analysis for Wade Hampon Census Area

Residential Electricity

The foundation of the entire analysis is the community-level electricity consumption data reported through the Alaska Power Cost Equalization (PCE) program. I used these data from years 2010 and 2011 to estimate a regression equation that shows how residential electricity consumption within the study area varies by household size. The regression shows that households of 3+ members use an additional 4,000 kWh per year than households of size 1 or 2.[8] This result is highly statistically significant and provides a good empirical basis for creating two distinct household types to analyze.

The Census provides data on the number of households of each type. I then calculated the residential electricity consumption of each type that is consistent with the regression equation discussed above and also yields the actual total consumption -- by all residential households -- of 8,789,315 kWh, which is a known data point. The resulting allocation is shown in Table 4. This example illustrates the general approach of allocating known total amounts among the two household types.

Table 4. Wade Hampton Population, households, and residential kWh, by household type

	Small HH (1-2 members)	Large HH (3+ members)	All HH
Population	703	6,221	6,924
% of total population	10%	90%	100%
Households	471	1,115	1,586
% of total HH	30%	70%	100%
Average household size	1.5	5.6	4.4
Residential kWh per HH	2,763	6,715	5,542
Total residential kWh:	1,300,734	7,488,580	8,789,315
Gal of diesel to generate:	98,540	567,317	665,857

Residential Space Heat

There is no data set with actual, measured, residential heating fuel consumption by rural Alaska households. However, fuel use for residential space has been studied and modeled as a

[8] This result is obtained by hedonic regression using the fraction of households with 3+ members in each community as an independent variable to explain average residential consumption in that community. Again, no household-level consumption data are available.

function of house size and heating degree days (Colt 2013, Alaska Energy Authority & WH Pacific 2012). The entire study area is in Alaska Climate Zone 8, as defined by the Alaska Building Energy Efficiency Standards with reference to heating degree days in the range 12,600 – 16,800.[9]

To estimate heating fuel use by housing type -- single-family, multi-family, and mobile home -- I used a sample of 318 houses that were audited and modeled as part of the Alaska Home Energy Rebate Program. These houses are all in Alaska climate zones 7, 8 and 9 and are known as the "ARIS Sample." I also obtained a separate sample of audited and modeled houses from the Alaska End Use Energy Study (Alaska Energy Authority and WH Pacific 2012). These houses are known as the "EUS Sample." As Table 5 shows, the resulting estimates of heating fuel use per house from these two samples agree well with each other and also with the estimates of 850 and 903 gallons per house given in the *Northwest Arctic Strategic Energy Plan*.[10]

Table 5. Estimated residential space and water heating fuel use by structure type

	ARIS rural sample (318 houses)	EUS Sample (328 houses)	Average of both samples			compare to NANA SEP
	million btu/yr	million btu/yr	million btu/yr	million btu/gal	gallons/yr	gallons/yr
Single-family	121	133	127	0.134	948	903
Multi-family	105	119	112	0.134	836	
Mobile Home	185	216	201	0.134	1,496	

The next step toward determining residential heating fuel use by small and large household types is to associate each household type – small and large -- with a mix of single-family, multifamily, and mobile home structures. The Census provides data on the total numbers of these structures for Wade Hampton. I allocated these total numbers of structures to households of differing sizes using professional judgment. The purpose of this allocation is to implement the idea that small households are more likely to live in multifamily housing or mobile homes.[11] With this allocation made, I calculated residential heating fuel use for each household type. This calculation is summarized in Table 6. Estimated use per household is slightly higher for small households than for large. This is partly because small households are

[9] See Alaska Housing Finance Corporation (2014).

[10] Northwest Arctic Leadership Team, no date (approx. 2009). The NWASEP uses both a "rough order of magnitude estimate" of 850 gallons per single-family house (p. 4) and an estimate of 129 gallons per house per month (p. 11) times 7 full months of heating season = 903 gallons per household per year.

[11] It would, of course, be more direct to use actual data on heating fuel use by households of different sizes. However, the data sets with audited houses do not include the number of people living in the structure. So this allocation attempts to use measured variation in heating fuel by structure type to generate some variation in heating fuel use by household type – small and large.

assumed to be more likely to live in mobile homes, which have very high modeled fuel consumption in the data samples used here.

Table 6. Wade Hampton estimated residential heating fuel use by household type

	Number of houses by HH type:			
	Small HH (1-2 members)	**Large HH (3+ members)**	**All HH**	**Fuel per house (gal/yr)**
Single family	421	1,060	1,481	948
Multi family	28	34	63	836
Mobile Home	21	21	42	1,500
Total houses	471	1,115	1,586	
Total fuel use (gal/yr)	454,668	1,064,832	1,519,500	
Average fuel use (gal/HH)	966	955	958	

Nonresidential electricity

Nonresidential customers use 61% of total Wade Hampton electricity, as shown in Table 7. Data are reported for sales to "commercial" "community facilities," and "government facilities" customers. However, these terms are in quotation marks because they may not include what one would expect. For example, both the Yukon-Kuskokwim Health Corporation headquarters offices and the YKHC regional hospital are classified as "commercial" customers, while schools are typically classified as government facilities.[12]

Table 7. Wade Hampton electricity sales by customer class

Customer type	kWh		generation efficiency kWh/gal	Diesel gal/yr	carbon fee $/yr
residential	8,789,315	39%	13.2	665,857	97,902
commercial	4,180,937	18%	13.2	316,738	46,570
community facilities	3,835,725	17%	13.2	290,585	42,725
government facilities	5,828,823	26%	13.2	441,577	64,926
unbilled	8,769	0%	13.2	664	98
Total kWh sold	22,643,568		13.2	1,715,422	252,221
nonresidential subtotal	13,854,253	61%		1,049,565	154,319

[12] Cady Lister, Alaska Energy Authority program manager, personal communication 12 June 2015.

There are two important allocations required in order to estimate how much of the carbon fees associated with nonresidental electricity are paid by each household type. The first allocation is called *local incidence*. The local incidence fraction is the proportion of the total carbon fees ultimately paid by local residents. For example, if all commercial electricity were consumed by locally-operated and locally-owned small businesses, then the local incidence of carbon fees for commercial electricity would reasonably be 100%. Conversely, if all commercial electricity were consumed by a Seattle-based fish processing company that does not sell locally, then the local incidence of the resulting fees would be essentially zero.[13]

I assume that the local incidence of reported "commercial" electricity costs in Wade Hampton is 50%. This is simply a best estimate recognizing that the following entities would not pass the fees through to local people: Regional health corporations; businesses serving tourists; businesses (such as a fish processor) exporting to nonlocal customers; or nonlocal business owners who cannot pass all of the fees through to local customers.[14] The assumed local incidence of community facilities electricity costs is 100% and the assumed local incidence of government facilities electricity costs is 0%. These assumptions are, of course, simplifications of a more complex reality.

Once the local share of nonresidential electricity costs has been determined, the second important allocation is to allocate the total local payments among the two household types. I do this by estimating the fraction of total regional household income accruing to each household type. The calculations are based on Census data that provides median income by household size. Several adjustments are needed to convert this distribution of median incomes into the desired total income amounts accruing to small and large household types.[15] The resulting shares are 19% of total income to small households and 81% to large households.

I used the total income shares to allocate the locally-paid share of commercial electricity cost and carbon fees to small and large households. For community facilities electricity I allocated the locally-paid share on an equal amount per household basis. I allocated government facilities electricity using total income shares, but the allocation is irrelevant because the assumed local incidence is zero. Table 8 summarizes the nonresidential electricity carbon fee allocations.

[13] To be completely precise, some small portion of fees might get passed through to locals if the fish processor aggressively cut its use and shifted some of the fixed cost of the utility onto other customers.

[14] The full amount of the fee must be shared between customers and owners, so if both groups are local, the local incidence of such fees is 100%. (This assertion ignores passing costs "backwards" to upstream suppliers.)

[15] The census data does not include mean income by household size. Hence, the key step is to adjust median incomes by household size to mean income by household size. I did this using a constant adjustment factor that did not vary across household sizes. I used trial and error (=Excel goal-seek) to find the adjustment factor such that the calculated grand total income amount for all households matched the known grand total amount of income earned by all households in the census area.

Table 8. Wade Hampton allocation of nonresidential electricity consumption and carbon fees to household types

	Total gal/yr	Total fee $/yr	Assumed local incidence	Total fees paid by all HH	Allocation method to HH types	Total fees paid by small HH	Total fees paid by large HH
commercial	316,738	46,570	0.50	23,285	income	4,461	18,824
community facilities	290,585	42,725	1.00	42,725	equal per HH	12,683	30,042
government facilities	441,577	64,926	0.00	0	income	0	0
Subtotal	1,048,900	154,221		66,010		17,144	48,867
Unbilled	664	98	0.43	42	pro-rated	11	31
Total nonres electricity	1,049,565	154,319		66,052		17,155	48,898

Nonresidential heating fuel

There is no systematic data on measured heating fuel use in nonresidential buildings in the study area. I therefore used parameters from the Alaska Village Energy Model (Colt 2013) to estimate nonresidential heating fuel as a linear function of nonresidential kWh.[16] The statistical parameter is 0.112 gallons heating fuel per nonresidential kWh. The resulting estimate of total nonresidential heating fuel is shown in Table 9.

Table 9. Wade Hampton estimated nonresidential heating fuel use

	nonres electricity kWh/yr	parameter: gal heatfuel per kWh electricity	Heating fuel gal/yr
commercial	4,180,937	0.112	469,734
community facilities	3,835,725	0.112	430,949
government facilities	5,828,823	0.112	654,877
Total nonresidential heating fuel			1,555,561

To allocate the total nonresidential heating fuel gallons and fees I used the same fractions for local incidence and the same allocation methods to household types as were used for nonresidential electricity. Table 10 shows the resulting allocation of carbon fees.

[16] The coefficients were determined using a data set of 312 nonresidential buildings for which both measured electricity consumption and measured heating fuel consumption (from bills) was included in the data.

Table 10. Wade Hampton nonresidential heating fuel allocation of consumption and carbon fees to household types

	Total gal/yr	Total fee $/yr	Assumed local incidence	Total fees paid by all HH	Allocation method to HH groups	Total fees paid by small HH	Total fees paid by large HH
commercial	469,734	69,066	0.50	34,533	income	6,615	27,917
community facilities	430,949	63,363	1.00	63,363	equal per HH	18,809	44,554
government facilities	654,877	96,288	0.00	-	income	0	0
Total nonres heat	1,555,561	228,716		97,896		25,425	72,471

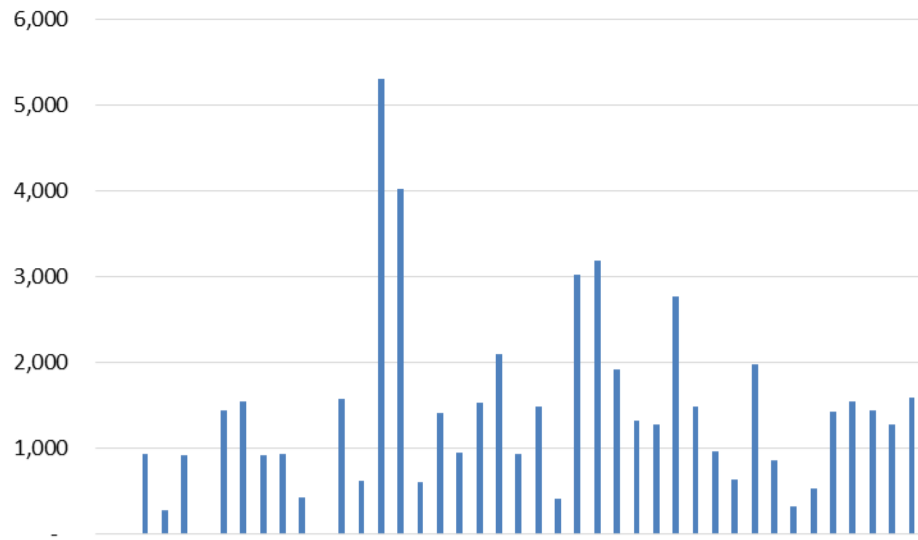
Personal land and water transportation

Personal land and water transportation includes all-terrain vehicles (ATVs), boats, trucks & cars, and snowmachines. There are two small household survey data sets that can be used to help estimate these uses. The first is a survey of 54 households in coastal northwest Alaska (Schwoerer 2013) that was used in the Alaska Village Energy Model (Colt 2013). There is high variation in reported use in this data set, as shown in Figure 8. However, regression analysis shows that this variation cannot be explained by household size.[17] Therefore, the best estimate from this data set is equal per-household use of 1,252 gallons per household per year.[18]

[17] The coefficient is an additional 77 gal/HH/yr for each additional household member, but the t-statistic is only 0.85, far below the critical value of 1.96.

[18] This estimate is based on 52 observations, dropping the highest and the lowest from the 54 in the raw data set. This trimming process is common as a way of controlling for outliers.

Figure 8. Variation in annual gallons per household used for local and subsistence transportation by 54 households in 5 coastal northwest communities



source: survey data collected by Schwoerer, described in Schwoerer (2013).

The second data set is from household subsistence surveys conducted in 12 interior (meaning non-coastal) communities by the Alaska Department of Fish and Game. These data remain confidential but were made available for inspection.[19] In this data set there are slightly more than 200 household observations for which reported transportation fuel use exceeds 1 gallon per year.[20] For these 200+ households, the average use per household is less than 600 gallons per household per year.

Based on these two data sets, I assume that 900 gallons per household per year is used by both small and large households for personal land and water transportation.

Personal air transportation

Personal air transportation is that which is paid for by local households. I estimate this consumption using the expenditure method (Kummel 2014). The Alaska IMPLAN economic model provides an "absorption coefficient" which says that for every dollar's worth of air transportion that is produced and sold, 31 cents worth of refined petroleum product must be

[19] We hope to complete a data sharing agreement with ADFG to allow these data to be presented in a revision of this report.
[20] 1 gal/yr is used as a data filter because It is not possible to tell whether values of zero indicate an affirmative reponse of "zero" or simply missing data or "don't know."

purchased. In essence, every dollar's worth of air travel includes 31 cents worth of fuel.[21] Assuming an average aviation fuel price of $3.00 per gallon (for a mix of jet and avgas),[22] the 31 cents per dollar equates to 0.1 gallons per dollar. This number agrees reasonably well with the figure of 0.15 gallons per dollar reported by Kummel (2014) based on data from the MIT Airline Data Project.[23]

To complete the calculation I assume that the annual expenditures of small and large households on personal air travel are $2,000 and $4,000 respectively. Table 11 documents the resulting estimates of total fuel use by each household type.

Table 11. Wade Hampton personal air transportation fuel use

	Small HH	Large HH	All HH
expenditures per household	2,000	4,000	
gallons fuel per $	0.10	0.10	
gallons per household	200	400	341
total gallons	94,160	446,080	540,240

Embodied carbon fees in goods and services

For rural Alaska two special features of the economy are important to the analysis of fuel costs and carbon fees embodied in goods and services. First, any local purchases of energy by commercial enterprises, such as food stores, are accounted for in the above analysis of nonresidential electricity use and nonresidential heating fuel use. Locally-produced heat and light becomes part of the output of the food store itself – a warm, lighted place to shop and a properly refrigerated space to store the jugs of milk. The isolated nature of rural Alaska communities allows for a relatively clear picture of these costs.

The second special feature is that the cost of many goods reflects the extensive use of energy-intensive air freight. Fay et al. (2013) cite an analysis by Northern Economics (2009) indicating that air freight shipments to off-road Alaska communities averaged 1,096 pounds per capita in 2007.

My estimate of fuel use due to air freight is based on a direct comparison of air freight fuel costs, fuel use, and tons of freight delivered. The data were developed by Fay et al. (2013, p. 20,

[21] M. Guettabi, Instiute of Social and Economic Research, University of Alaska, personal communication. April 15, 2015.

[22] The use of $3.00 is a "round number" assumption based on consideration of averaging over jet fuel and avgas, and averaging the prices paid mostly in Anchorage but also in outlying communities, especially regional hubs.

[23] http://web.mit.edu/airlinedata/www/default.html

p. 34) from Department of Transportation flight segment statistics.[24] The analysis is summarized in Table 12 and the bottom line is that rural Alaska residents such as those in the study area annually use about 65 gallons of fuel per person – both jet fuel and aviation gasoline – for air freight. A local incidence of 1.00 is assumed. Clearly some air freight costs would not be paid by local residents, but using the high value of 1.00 accounts for some other transportation costs, such as barges, that are not explicitly calculated. Allocating the total payments on an equal per-person basis, each person would pay about $9.00 in carbon fees in 2016 due to higher fuel costs for air freight.[25]

Table 12. Wade Hampton estimated annual carbon fee per person due to air freight

	units	2006	2007	2008	2009	2010
Average price aviation fuel	2011$	2.46	2.60	3.30	2.03	2.51
Cargo delivered by cargo-only flights	tons	60,524	64,613	63,674	54,787	57,504
Fuel used	gallons	8,009,018	7,419,954	7,568,123	6,524,065	6,505,137
	gallons per ton	132	115	119	119	113
Air freght pounds per person				1,096		
Air freight tons per person				0.55		
Gallons per person		73	63	65	65	62
Total gallons for region				450,987		
Total carbon fee to be allocated				60,274		
Local resident incidence				1.00		
Carbon fee per person				$ 8.71		

Carbon fee calculations

With all of the electricity and fuel consumption quantities estimated, it is straightforward to calculate carbon fees for each household type.[26] Table 13 shows this tally. Small households would pay an average of $424 while large households would pay an average of $547.

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[24] Raw data comes generally from the Bureau of Transportation Statistics, available at www.transtats.bts.gov . See Fay et al (2013), pp. 19-20 and Table C-1 at p. 34 for discussion.

[25] Another potentially useful data set is the U.S. Department of Agriculture's "Cost of Food at Home" series which covers some rural communities over several years. Comparison of annual changes in food costs with annual changes in fuel costs could potentially yield a useful estimate of the degree to which higher fuel prices are actually passed through to the cost of goods in rural Alaska.

[26] In doing so, I make no further adjustment for the effects of the Alaska Power Cost Equalization program (PCE) subsidy. Although according to the PCE program formula a large fraction of the carbon fee on residential electricity would be paid for by the program, in fact total PCE payments are limited by available funding; payments are pro-rated down when total funds are insufficient to cover total calculated payments. In recent years th Alaska Legislature has made annual appropriations to add money to the amounts drawn from the PCE Endowment Fund. It is extremely unlikely that these appropriations wil continue, let alone increase.

Table 13. Wade Hampton summary of carbon fees paid per household for small and large households

	Total gal/yr	Total fee $/yr	Local inci - dence	Total fees paid by all HH	Total fees paid by small HH	Total fees paid by large HH	Fee per HH paid by small HH	Fee per HH paid by large HH
Electricity								
residential	665,857	97,902	1.00	97,902	14,489	83,413	31	75
commercial	316,738	46,570	0.50	23,285	4,461	18,824	9	17
community facilities	290,585	42,725	1.00	42,725	12,683	30,042	27	27
government facilities	441,577	64,926	0.00	0	0	0	0	0
unbilled	664	98	0.43	42	11	31	0	0
Space & water heat								
residential	1,519,500	223,414	1.00	223,414	66,851	156,564	142	140
commercial	469,734	69,066	0.50	34,533	6,615	27,917	14	25
community facilities	430,949	63,363	1.00	63,363	18,809	44,554	40	40
government facilities	654,877	96,288	0.00	0	0	0	0	0
Pers. land/water transpo	1,427,400	190,772	1.00	190,772	56,630	134,142	120	120
Personal air transport	540,240	72,932	1.00	72,932	12,712	60,221	27	54
Fuel used for airfreight	450,987	60,883	1.00	60,883	6,178	54,705	13	49
Total	7,209,110	1,028,939		809,852	199,438	610,414	424	547

A final adjustment to the calculated carbon fees is necessary before comparing total fees to total dividends. The PCE data that underlies the above analysis does not cover all communities in the region. The calculated total fee amounts are therefore adjusted upward to reflect the count of all households from the 2010 Census. For example, in Wade Hampton the community of St. Mary’s (population 507 in 2010) is not included in the data, so the PCE data covers only 1,586 households and must be adjusted up to reflect the census count of 1,745 total households.

Results for Wade Hampton

In Wade Hampton, small households would receive $24 more in dividends ($448) as they pay out in fees ($424), while large households would collect an average of $876 in annual dividends while paying an average of only $547 in fees. Overall, people in the region would receive net cash benefits totaling $415,458 in 2016 (Table 14).

Table 14. Wade Hampton results: initial year dividends and fees

	All HH	smal HH	large HH
Total Dividends	1,306,500	231,900	1,074,600
Total Fees	891,042	219,432	671,610
Total net cash to region	415,458	12,468	402,990
Average dividend per HH	749	448	876
Average fee per HH	511	424	547
Average net cash benefit	238	24	328

Both small and large households in Wade Hampton get initial net cash benefits under the CFD policy, net benefits of $328 per year for large households. The net benefits would likely increase over time, but future outomes will also likely depend on increases in energy efficiency and further displacement of diesel with low-carbon energy sources such as natural gas, propane, or renewables.

It is important to acknowledge that there will likely be some households – especially smaller ones -- for which fees exceed dividends. That's because this analysis does not capture the complete range of variation in energy use. To take one example, single-person households who engage in significant personal transportation could easily pay more in fees than the $300 dividend they would receive. Without household-level data that specifies the energy consumption behavior of individual households, it is not possible to estimate precisely how many people or households households might fall into this category.

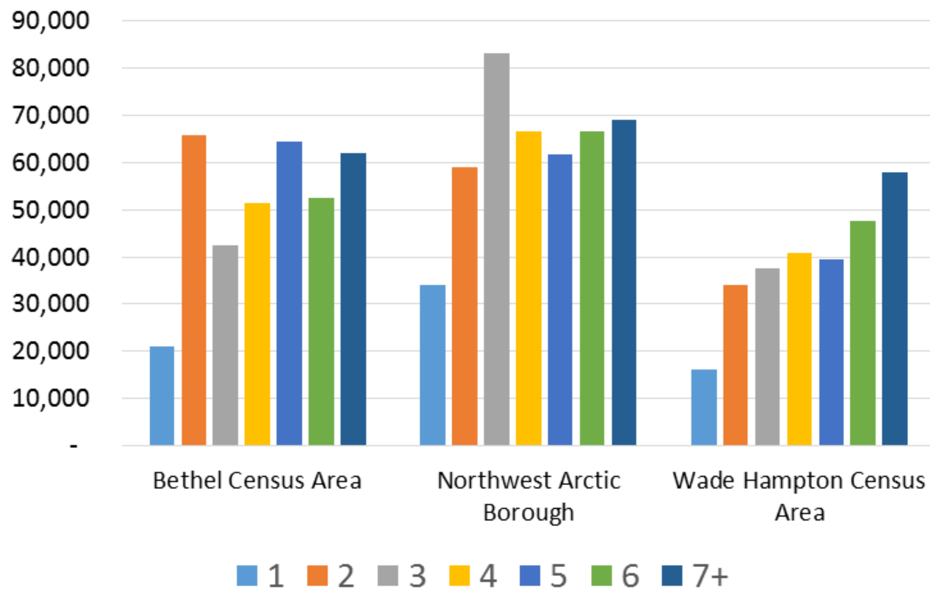
Assumptions and results for other regions

Bethel Census Area

Bethel Census Area includes the regional hub of Bethel itself, and has a total poulation of about 18,000 -- more than 3 times as many people as Wade Hampton. There is significant "commercial" electricity consumption, much of which might be associated with Alaska Native Nonprofit organizations such as Y-K Health Corporation. There is higher income, which is reflected in higher residential electricity use. Figure 9 documents this difference, showing how the entire distribution of median income across household sizes is higher in the Bethel Census Area than in Wade Hampton.

The results for the Bethel Census Area are that large households would receive average dividends that exceed average fees by $297, while for small households average dividends exceed average fees by $9 per household.

Figure 9. Distribution of median income by household size in each study region



Northwest Arctic Borough

The Northwest Arctic Borough has significantly higher total electricity consumption than either of the other two regions. On a per-household basis, it is 20% higher than in Bethel Census Area and almost 40% higher than in Wade Hampton. This difference, which may reflect colder weather, drives the calculations toward higher estimated fuel use. As a result, Northwest Arctic Borough households in the small household group are estimated to pay initial fees that exceed dividends by about $41 per year. It is the allocated energy use of commercial and community facilities that drives this result. If the assumed local incidence fractions are too high, many small households would actually be net gainers with dividends exceeding fees.

Study area summary

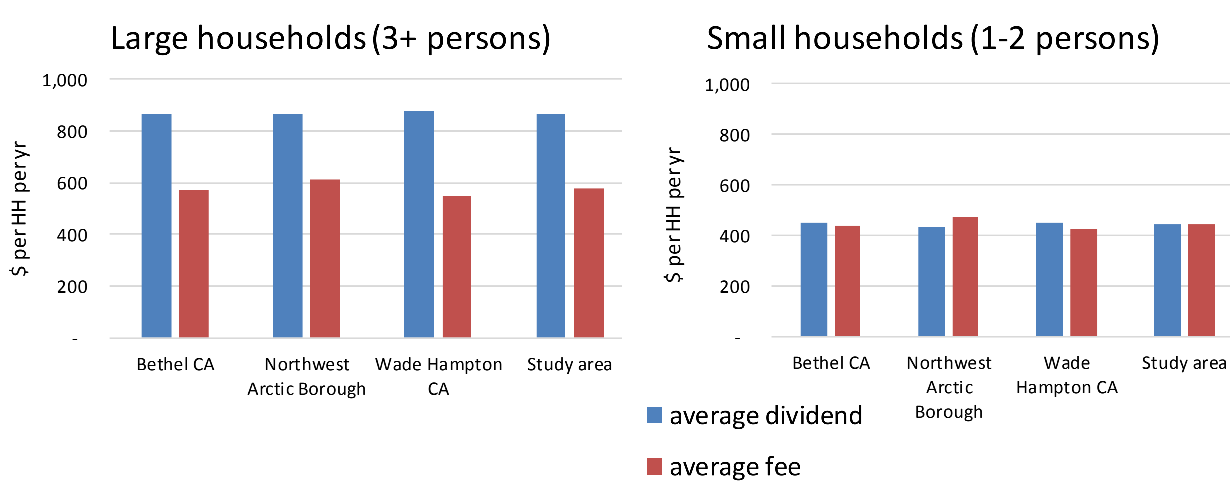
Table 15 and Figure 10 summarize the analysis of this section. They show the initial year outcomes for all three regions. Bethel Census Area and Wade Hampton households pay essentially the same fees and receive roughly the same dividends. In these regions small households essentially break even, while large households receive an average annual net cash benefit of about $300. By contrast, in the Northwest Arctic Borough small households pay $41 more in fees than they receive as dividends, while large households get a net cash benefit of $250.

Considering the study area as a whole, total dividends exceed total fees by more than $1.5 million. More than 91% of study area households, comprising 97% of the study area population, would receive average dividends exceeding average fees in 2016. While there are undoubtedly financial winners and losers within each household group, it is reasonable to conclude that the vast majority of people in the study area stand to initially gain more in dividends than they would pay in fees.

Table 15. Results summary: initial year dividends and fees for all regions

	Bethel Census Area	Northwest Arctic Borough	Wade Hampton Census Area	Overall Study Area
Initial year dividends and fees				
Total dividends	3,257,550	1,346,550	1,306,500	5,910,600
Total fees	2,408,276	1,077,897	891,042	4,377,214
Net cash benefit to region	849,274	268,653	415,458	1,533,386
Small households (1-2 people)				
Average dividend per HH	447	434	448	444
Average fee per HH	438	475	424	444
Average net cash benefit per HH	9	(41)	24	(0)
Number of households	1,846	727	518	3,091
Share of population	16%	15%	10%	14%
Large households (3+ persons)				
Average dividend per HH	867	865	876	869
Average fee per HH	570	615	547	575
Average net cash benefit per HH	297	250	328	294
Number of households	2,805	1,192	1,227	5,224
Share of population	84%	85%	90%	86%

Figure 10. Summary of effects on large and small households



4. Discussion

This paper has attempted to explore the differing amounts of carbon fees and dividends that individual households in different regions might experience. While dividend amounts can be calculated with great precision, at least for the first several years, there is simply not enough data to make strong conclusions about the fees that individual households would pay. By considering two distinct types of households, the analysis has shown that larger households are likely to see significant net cash benefits while smaller households are likely to break even or pay slightly more in fees than they receive in dividends. In the study area 86% of the population lives in a household with 3 or more members. In Wade Hampton, that fraction is 90%, and energy use is relatively low. The carbon fee and dividend concept appears to be relatively well-suited for areas like the three regions analyzed here; it favors larger households with relatively low energy use, and could initially deliver milllions of dollars of net cash benefits to rural Alaska.

This analysis has necessarily focused on initial year numbers. Both future dividends and future fees are uncertain. Future dividends will increase as the fee per ton goes up, but the total amount available for distribution also depends on aggregate national CO2 emissions, which would likely fall under the influence of increasing carbon fees. Future fees, on the other hand, can be moderated, or even eliminated, if rural Alaska communities can continue to increase energy efficiency and reduce dependence on diesel fuel.

The importance of nonresidential local energy use

The category of "commercial" electricity use looms large in the analysis, because it is a large amount and because the portion of the associated carbon fees paid by local residents is likely significant, but unknown. Furthermore, it is important to remember that in this analysis nonresidential heat is estimated a simple linear function of nonresidential electricity, which amplifies the importance of nonresidential electricity. Table 16 shows the variation among the study regions in "commercial" and other categories of nonresidential electricity use, all expressed in terms of kWh per household (=residential customer). The table also shows the dramatic effect of removing the hub communities of Bethel and Kotzebue from the calculations.

Table 16. Nonresidential electrcity use per residential customer

	commercial	comm facil	govt facil	Total
Total Study Area	5,848	1,421	2,155	14,859
Bethel Census Area	6,910	810	1,724	14,537
Northwest Arctic Borough	6,571	2,156	2,117	17,502
Wade Hampton Census Area	2,360	2,165	3,289	12,779
Bethel CA excluding hub	2,255	977	1,497	9,247
NWAB excluding hub	3,268	2,551	3,149	14,658

Further research could profitably look more carefully at these electricity consumption categories, perhaps by using individual customer billing data.

Use of Public Use Microdata (PUMS) to check results

The Public Use Microdata Sample (PUMS) from the American Community Survey year 2013, 5-yr estimates data set provides a potentially powerful tool for household-level analysis of carbon fees and dividends. The main drawback of PUMS data is that all of rural Alaska, plus some large communities like Kodiak and Sitka, are lumped together as one geographic area known as PUMA 400. It is not possible to tell whether a household in the data set is from Southeast or from Wade Hampton. A single large area would not be a problem if the data set contained estimates of electricity and fuel consumption for each household. However, it does not. PUMS does contain self-reported *expenditures* on electricity and heating fuel. But the variation in fuel prices within the PUMA is so great that it must affect the reported expenditures by at least as much as variations in quantities of fuel used.[27]

Despite these drawbacks, the Alaska PUMS sample for rural areas, known as the "Subsistence Alaska PUMA" and numbered PUMA 400, can still provide useful evidence about potential dividends and fees. I used the PUMS sample with several auxiliary assumptions and side calculations to estimate carbon fees due to residential energy use and to compare the fee for each household in the sample to its dividend (which can be easily calculated from the household size).

The results to date are quite preliminary, but they generally corroborate the analysis above. For example, more than 99% of households in the sample would receive sufficient dividends to defray the fees associated with their own household residential electricity and fuel use. About 86% would receive enough dividends to cover twice that amount. The analysis in Section 3 suggests that total carbon fees for both direct and indirect purchases of energy are about 1.9 times the fees due to residential heating fuel and electricity. Therefore, the tentative conclusion

[27] This problem would be solved if the ACS asked about and reported the prices associated with the expenditure data. There is no such data.

from the PUMS household-level data is that more than 86% of all households in the geographic area known as the “Subsistence Alaska PUMA” would receive enough dividends to cover all of the fees considered in Section 3 (residential and nonresidential heat and electricity, personal land, water, and air transportation, and fuel for air freight). This 86% fraction agrees well with the Section 3 analysis above, which found that roughly 91% of households could expect to receive dividends greater than fees.

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